The Accumulation of Arsenic in Drinking Water Distribution Systems

By

Darren Lytle and Thomas Sorg

United States Environmental Protection Agency

26 W. Martin Luther King Dr.

Cincinnati, Ohio 45268

Lytle.darren@epa.gov

Acknowledgements

- Abraham Chen, Bruce Sass, Lili Wang- Battelle Memorial Institute
- Christy Muhlen, U.S. EPA
- Rachel Copeland, U. of Cincinnati/U.S. EPA
- Utility managers and personnel

Arsenic Rule

Arsenic MCL was reduced from 0.05 mg/L to 0.01 mg/L (10 ug/L).

Iron-Based Arsenic Removal Processes

- Adsorptive properties of iron mineral toward arsenic are well known
- That knowledge is the basis for many arsenic treatment processes
  - Iron removal
  - Coagulation with iron coagulant
  - Iron-based adsorption media
- Reasonable that iron-containing corrosion deposits and sediment will also adsorb As
- Other solids??

Concentration of Arsenic in DW Distribution Systems Solids

- Source water (natural, contamination)
- Particles that enter and settle the DS
  - iron oxides
  - calcium carbonate?
  - manganese dioxide?
- Adsorption on corrosion deposits (Fe, Cu, Zn, Pb)
- Adsorption on sediment
- Precipitation of arsenic mineral phase

Background

- AWWA Opflow report by Reiber (2000)
  - Midwestern utility made treatment change
  - As < 7 :g/L
  - Colored water event
  - Water samples very high As (>300 mg Fe/L)
  - Presumably arsenic tied to iron deposits
- Is the potential for similar occurrences widespread?
- Arsenic Rule does not consider As levels in the distribution system.

Project Objective

Determine the composition of solids collected from DW DS where measurable amounts of arsenic in the finished water

- pipe sections (corrosion products, deposits, etc.,)

- fire hydrant flush (loose particles, corrosion products, etc.,)

Project Approach

- Identify and contact utilities (Battelle, State Agency, past relationships)
- Coordinate sample collection
  - Hydrant flush (5 liter bottles)
  - Pipe section (when available)
  - Water chemistry (As speciation, iron speciation, general water chemistry)
- System description
- Analyze solids

Utility Selection

- Battelle, State assistance, past relationships
- Arsenic in raw/treated water
- Over 15 utilities- Ohio, Michigan, Indiana, others
- Range of treatment
  - Aeration/softening/chlorination
  - Fe & Mn removal (3)
  - None
  - Chlorination
  - Chlorination/polyphosphate (2)

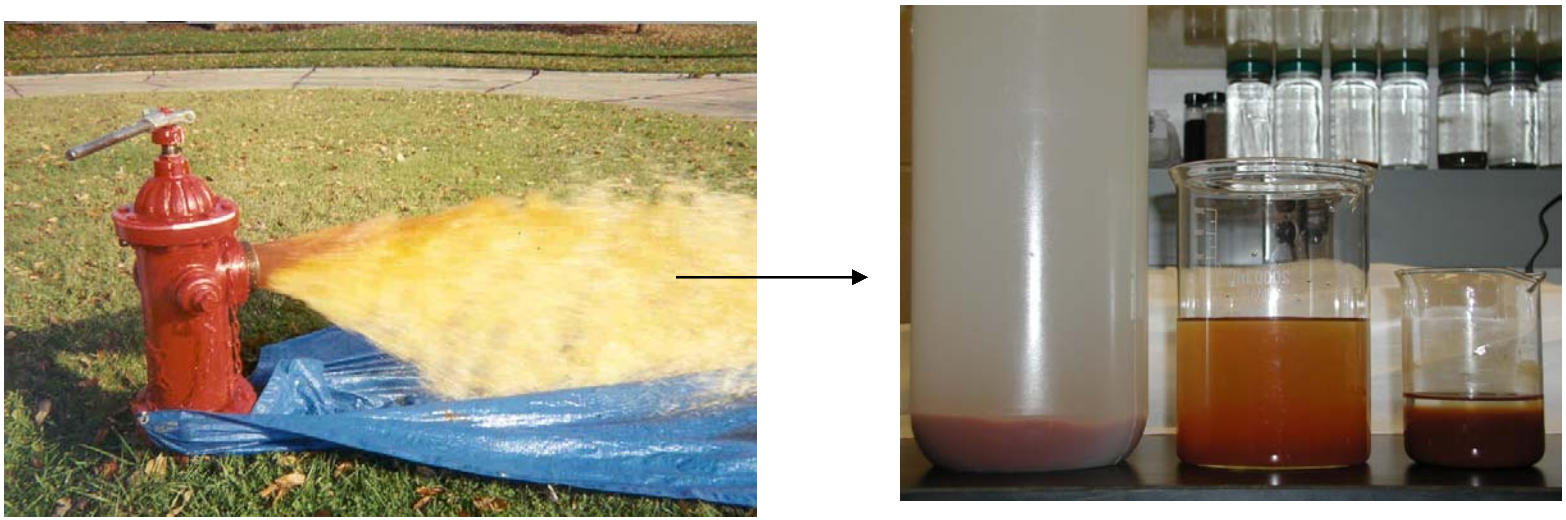
Water Chemistry

- pH 7-8
- 2-31 :g As/L
- <detection- 2.77 mg Fe/L
- Relatively hard, 11-116 mg Ca/L
- <detection-0.59 mg Mn/L

Fire Hydrant Flush

- Normal hydrant flushing schedule
- Simply place 5 L bottle in flush stream
- Concentrate sample by sedimentation and centrifugation
- Grind (75 :m sieve)
- Dry

Fire Hydrant Flush



Pipe Material

- Took what we could get when we could get it.
- Any material was acceptable (PVC, AC, cast iron, copper, etc..)
- Scrape (layering if possible), grind

PVC pipe

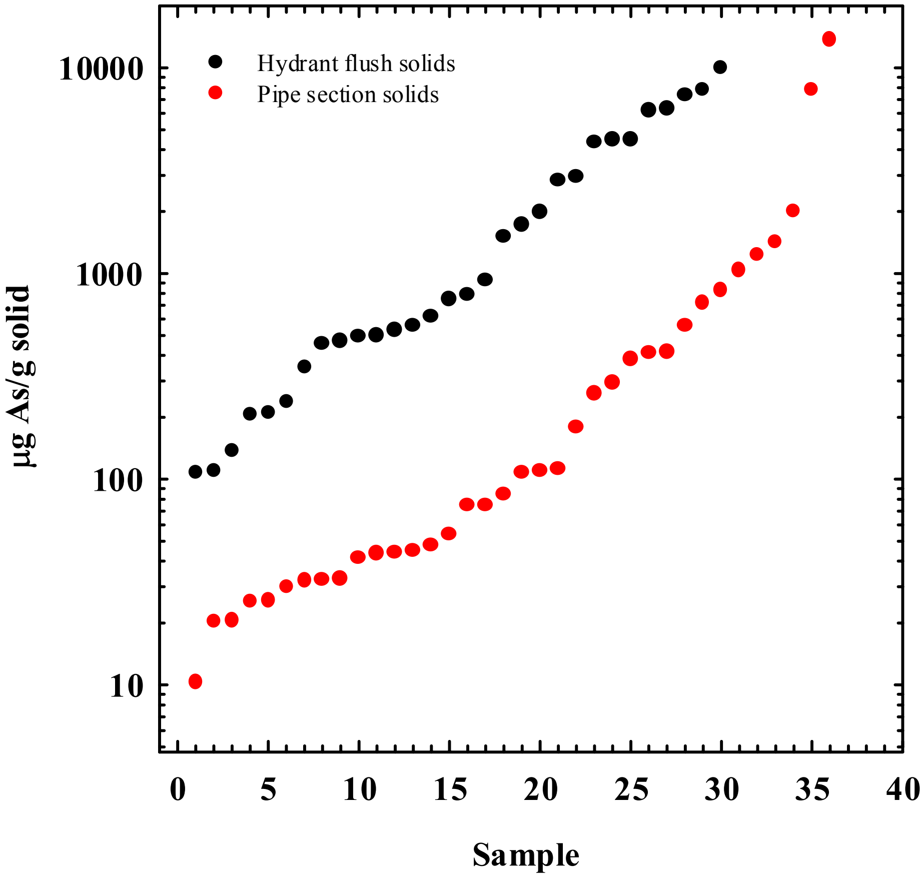
Iron pipe

Solids Analysis

- Acid digestion/ICP-MS (Battelle)
  - Ca, Mn, Fe, Mg, P, Si, As
  - Units
- XRF (Univ. of Cincinnati Geology Dept.)
  - Cl, S, Ba, Ca, Mn, Mg
- XRD
  - Mineral phases
- Electron microprobe-WDS (Battelle)
  - Quantitative elemental mapping
- SEM-Wavelength dispersive spectrometer- imaging and elemental mapping

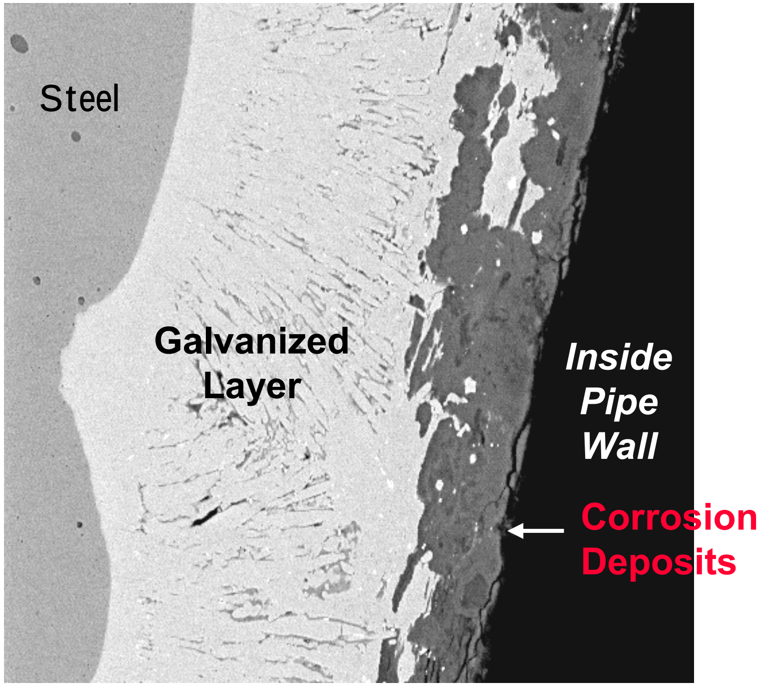
Arsenic Accumulation the DS

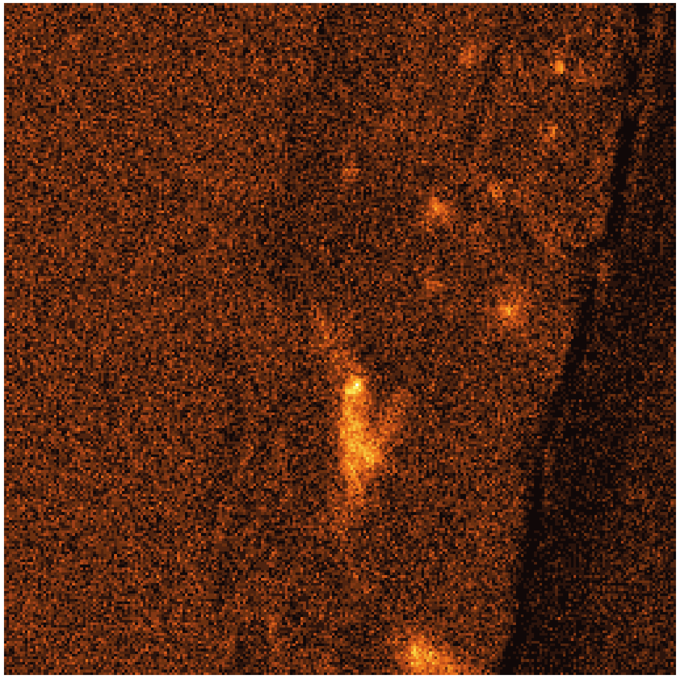
ICP-MS analysis



PVC pipe- Sample 3-1

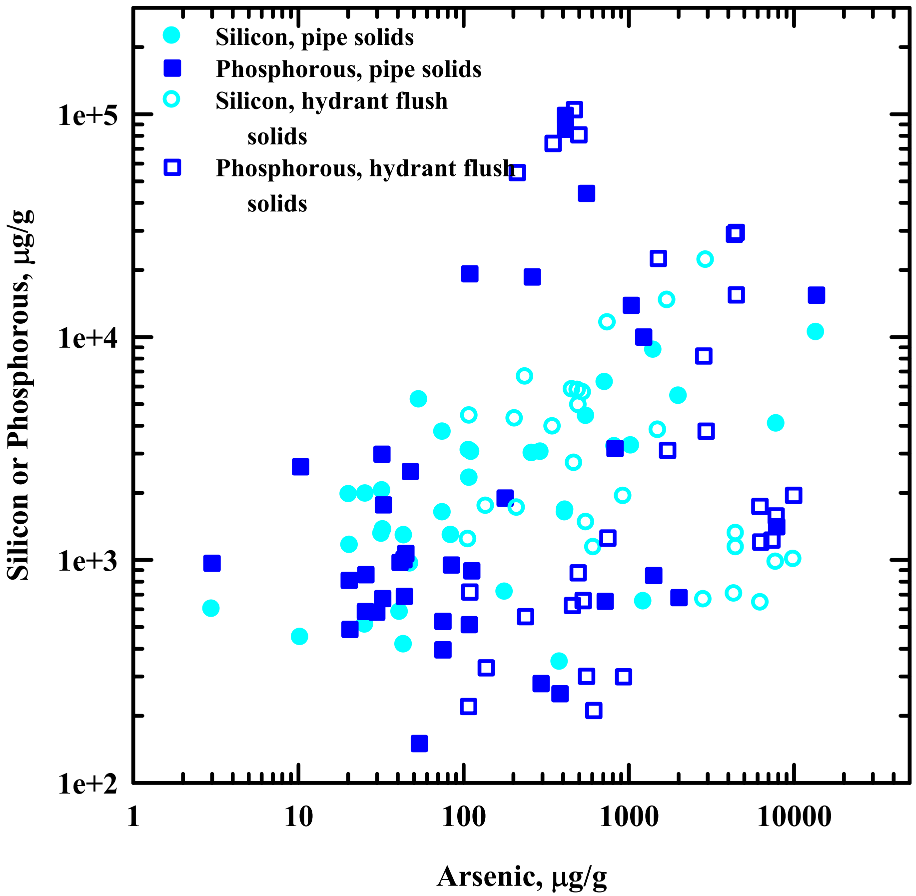
Elemental Mapping- Microprobe-WDS analysis





Arsenic distribution

Relationship Between Arsenic, and SiO_2 and PO_4



Arsenic Composition Relationships

- Initial arsenic- no
- Pipe or flush- no
- Water chemistry- no
- Treatment- no
- Material age- ??

What Does this Mean?

- Arsenic does concentrate in DW DS
- Suggests that disturbances to DS may release arsenic
  - Particle destabilization
  - Desorption
  - Competitive desorption
  - Redox chemistry changes
  - Microorganisms
- Health impacts??
- Need for future investigation

Arsenic Release

- Particle mobilization
  - Hydraulic changes
  - Water chemistry changes
  - Hydrant flushing
- Desorption
  - Water chemistry changes
  - Treatment changes

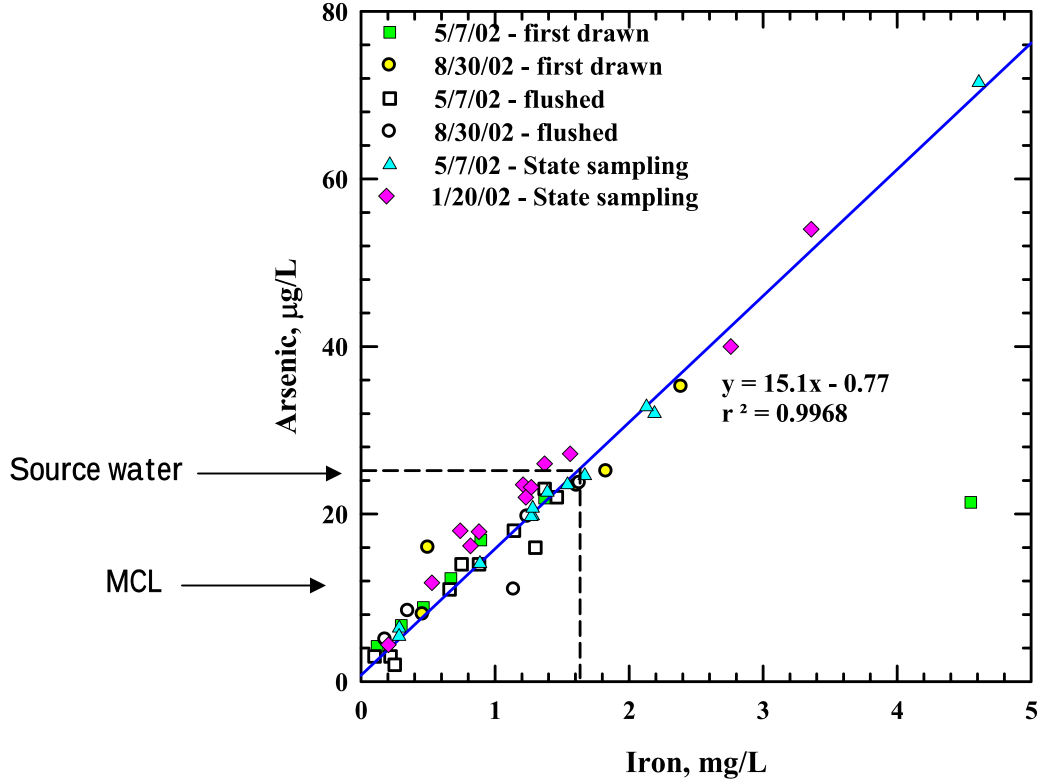
Case Study 1: Particulate Release of Arsenic in Distribution Systems

- Colored water events led to sampling and the finding that As levels (>100 :g/L)
- Also high iron levels (>15 mg/L)
- Lawsuit and media attention
- 73 mg Ca/L, 32 mg Mg/L, 17 mg SiO_2/L, pH mid 7's
- 24 :g As/L, 1.6 mg Fe/L
- chlorination

Case Study 1: Particulate Release of Arsenic in Distribution Systems

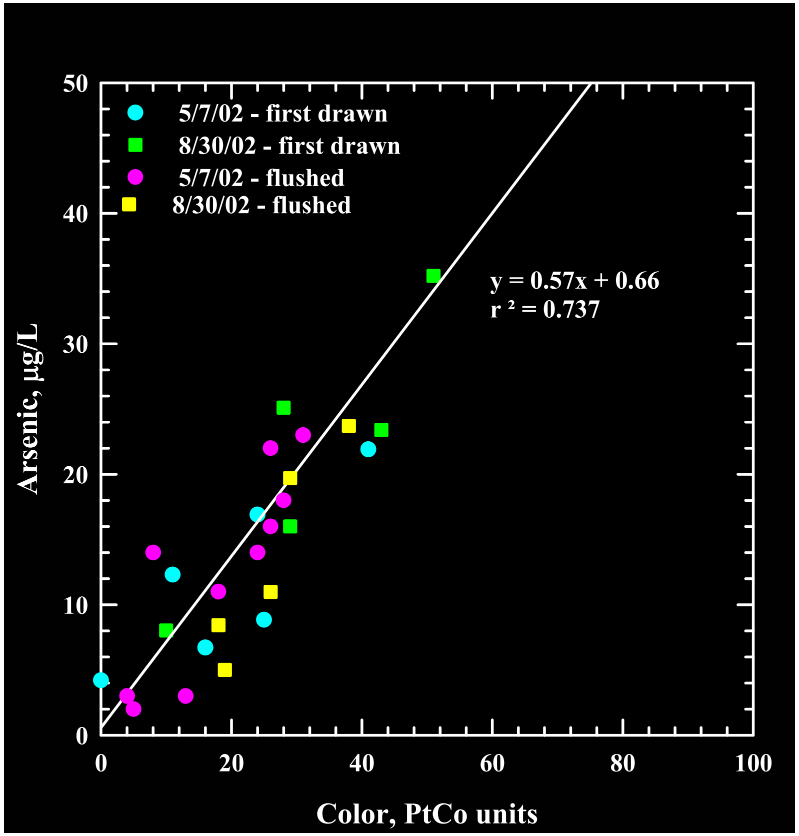
Case Study 1:

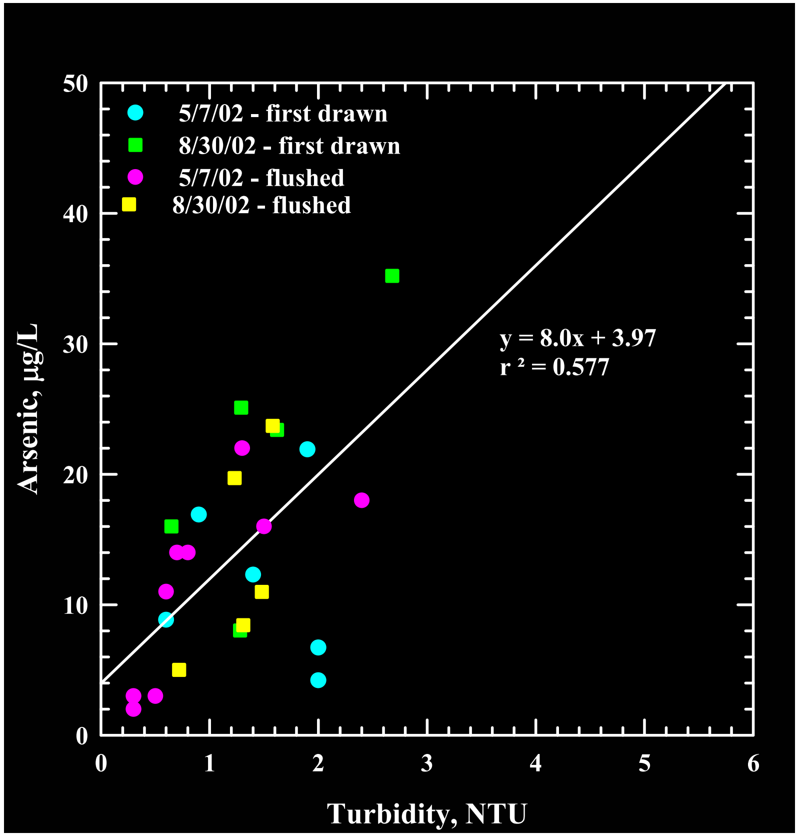
Relationship Between Arsenic and Iron in Distribution System Samples



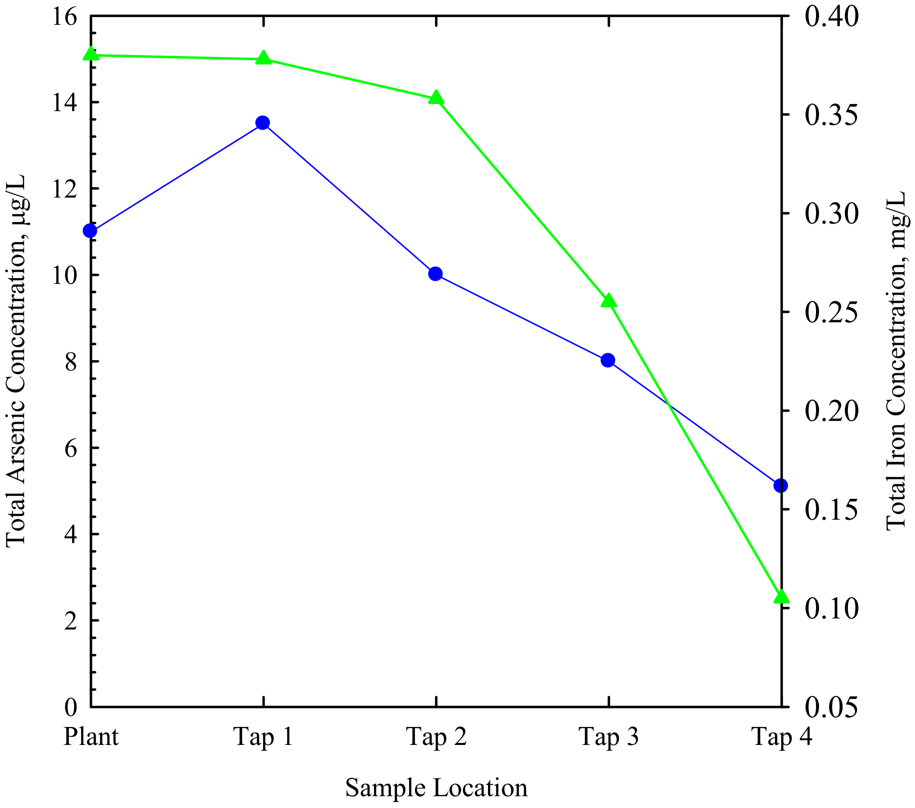
Case Study 1:

Relationship Between Arsenic and Color/Turbidity in Distribution System Samples

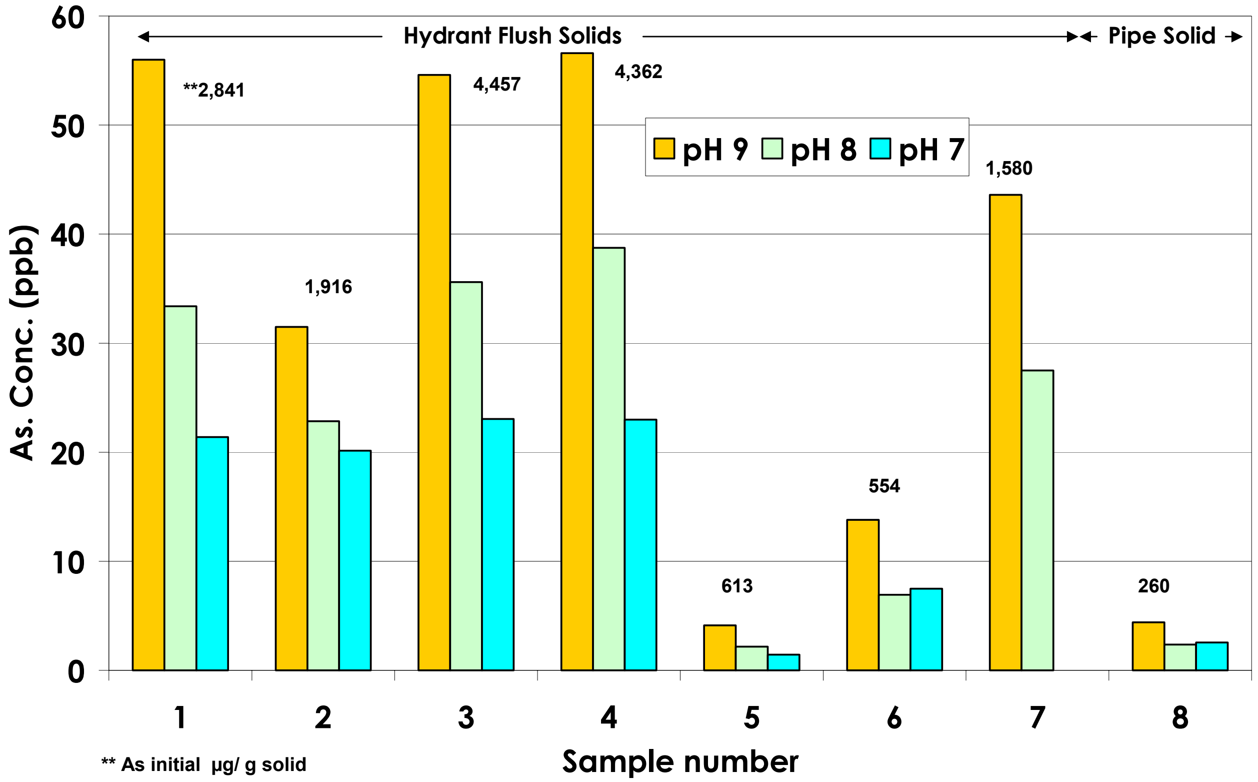




Case Study 2: Particulate Release of Arsenic in Distribution Systems



Research: Desorption from Drinking Water Distribution System Solids



- Samples 1, 2,3,4 and 7 correspond to the same Utility
- The majority of these solids are hydrant flush material

What do we do about it?

- Remove arsenic from source
- POU devices
- Distribution system maintenance
  - Corrosion control
  - Flushing
- Awareness of indicators
- Research- better understanding of factors that impact As release

Conclusions

- Arsenic does concentrate in DW DS
- Amount of arsenic was independent of variables considered in this study
- Turbidity and color are indicators of arsenic release when particulate iron was involved
- More research is needed